CONCRETE
AND
CONSTRUCTIONAL ENGINEERING

INCLUDING PRESTRESSED CONCRETE

SEPTEMBER, 1954. Vol. XLIX, No. 9

FORTY-NINTH YEAR OF PUBLICATION

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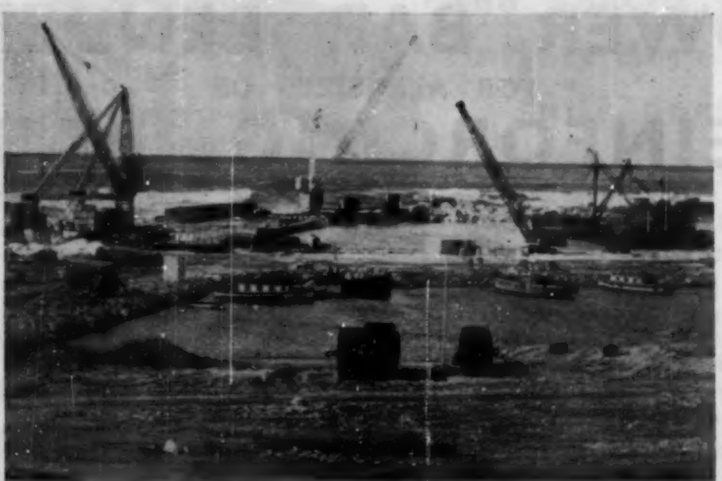

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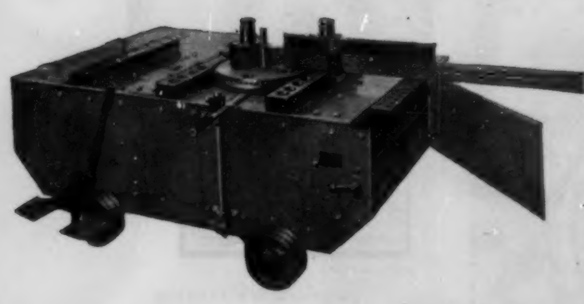

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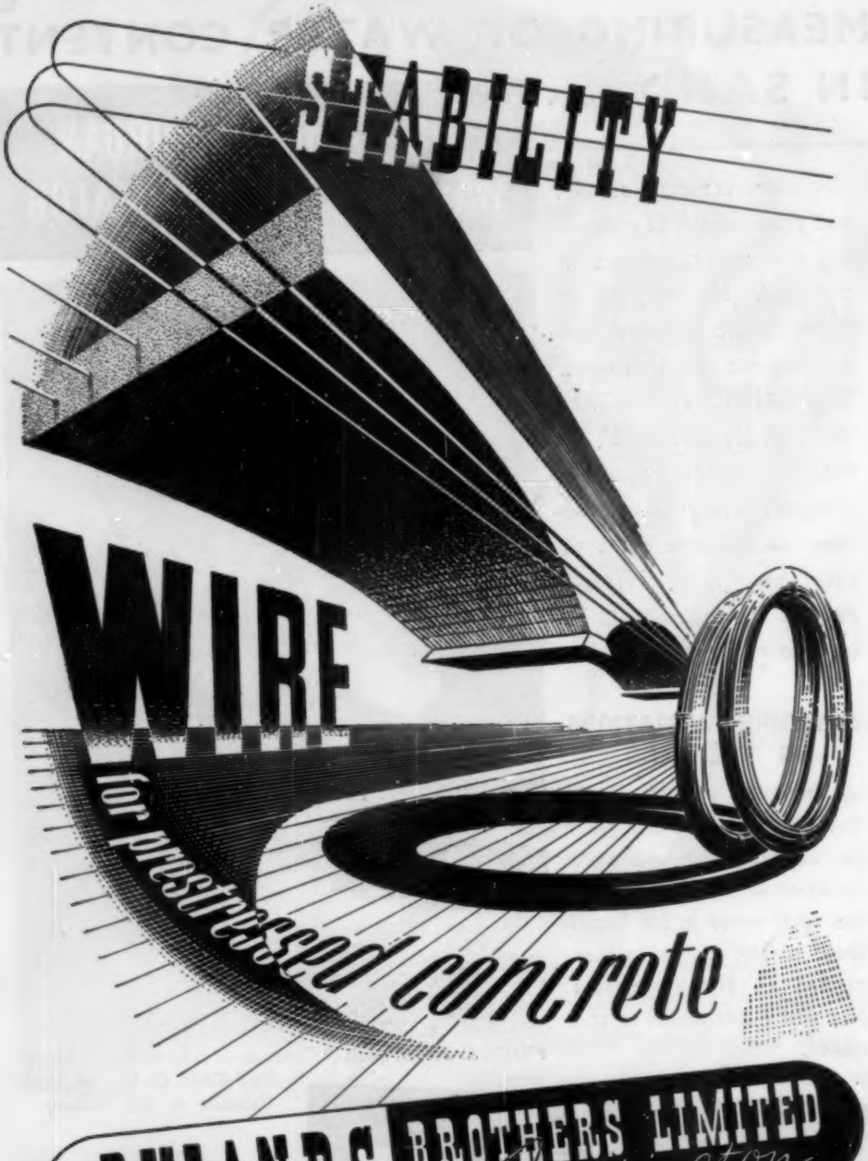

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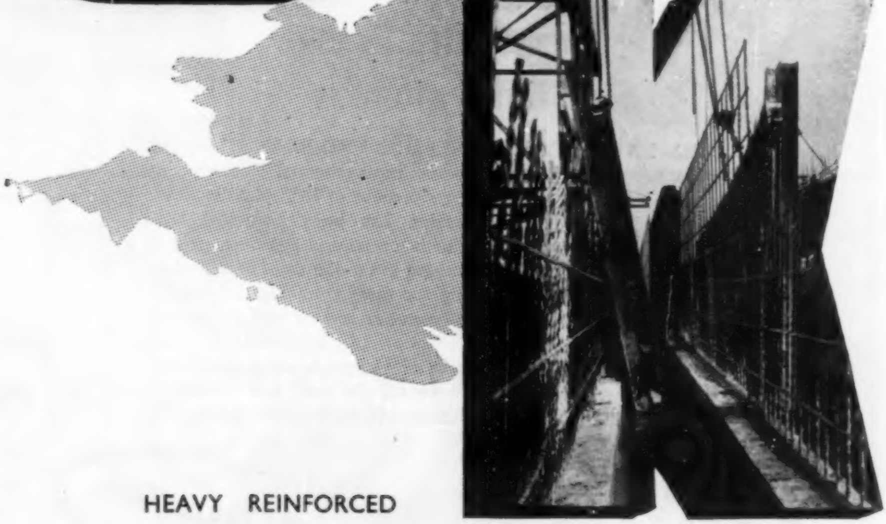

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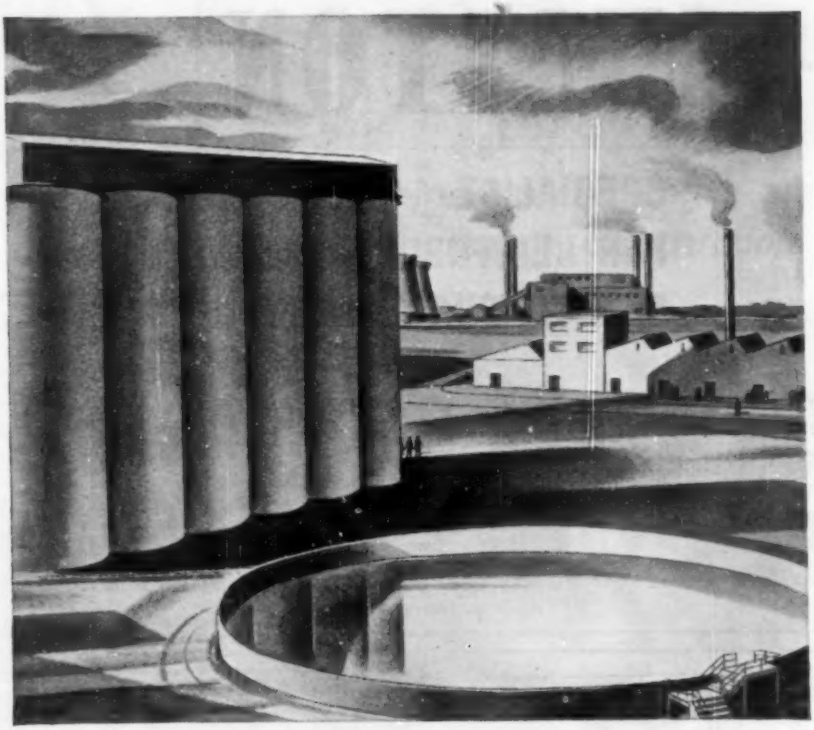

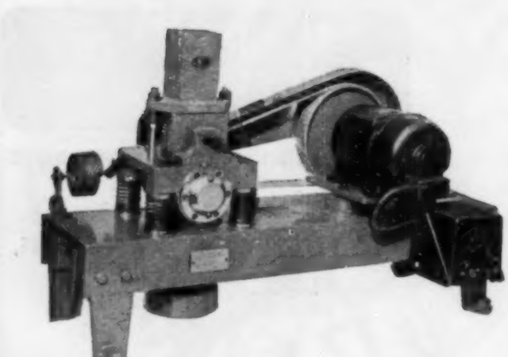

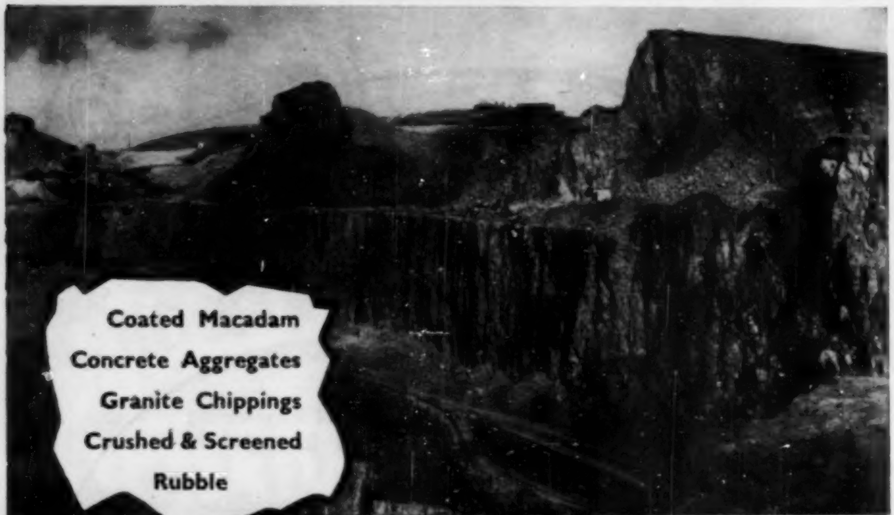
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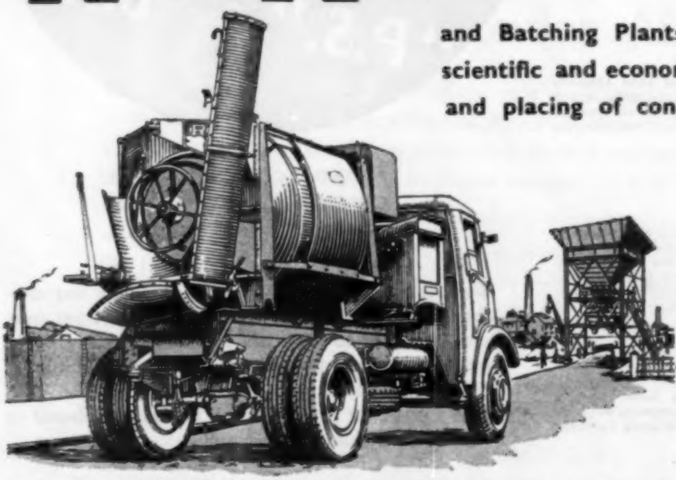

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Volume XLIX, No. 9. LONDON, SEPTEMBER, 1954.

EDITORIAL NOTES

The Use of Pulverised-fuel Ash in Concrete.

FOR more than thirty years the dust from pulverised fuel collected in precipitators and the chimneys at electricity works has been used in the United States to replace part of the cement content of concrete. Recently some experiments have been made on this subject by the British Electricity Authority, and the results are similar to those published in the U.S.A. in the year 1937. The dust, which is a waste product (known in the United States as " fly-ash " and described in this country as pulverised-fuel ash), has a chemical composition similar to that of pozzolana, and therefore has some cementitious properties because the silica content can, during a period of several months, combine with the lime in hydrated cement to form cementitious compounds. Also, the presence of the ash slightly improves the workability of concrete. The fineness of the ash varies, but generally it is similar to that of Portland cement. The content of combustible material varies considerably according to the type of coal used and the conditions of combustion in the furnace, and it appears that it may be from 3 per cent. to more than 12 per cent.

The reported laboratory tests of concrete in which ash from British power stations is incorporated all show a reduction in strength at early ages. For example, in tests on 1 : 2 : 4 concrete made by the British Electricity Authority concrete in which the cement was not diluted and concretes in which up to 20 per cent. of the cement was replaced by ash (both measured by weight) containing 5 per cent. of carbon all had compressive strengths of about 5000 lb. to 5700 lb. per square inch at one year. At earlier ages, however, the strength of concretes made with the diluted cements was much less than that of concrete made with undiluted cement. Concrete in which 20 per cent. of the cement was replaced by ash had strengths of 2000 lb. per square inch at seven days, 2800 lb. at fourteen days, and 3200 lb. at one month, compared with 2800 lb. per square inch at seven days, 3200 lb. at fourteen days, and 3900 lb. at one month for control specimens made with undiluted cement. When higher proportions of cement were replaced by ash the compressive strengths were lower still ; for example, when 40 per cent. of the cement was replaced by ash the strength of 1 : 2 : 4 concrete was only about 1400 lb. per square inch at seven days and 2100 lb. at one month. The strength at one year of concrete containing up to 20 per cent. of flue ash from pulverised fuel may be the same as that of Portland cement concrete without ash,

and the only adverse effect shown by tests is slower hardening. This phenomenon is common to all types of Portland cement; that is, some gain strength quickly after hydration while others gain strength at a slower rate, but at the end of a year or so they all have about the same strength. The initial and final setting-times of cement containing the ash are retarded by about half an hour. Tests made in the United States have shown that the workability and resistance to chemicals of concrete are improved without reduction in the strength at 28 days if the quantity of cement omitted is replaced by about twice the quantity (by weight) of ash; these tests might also usefully be copied with ash from British electricity works in order to see if the ash can be used to produce better concrete without delaying the hardening.

Tests have been made by the British Electricity Authority on the effect of varying proportions of the combustible content of the ash. Ordinary Portland cement was diluted with 20 per cent. of ash, and the results suggest that a carbon content of up to 8 per cent. had little further effect in reducing the rate of hardening. The British Standard for Portland cement limits the loss on ignition to 3 per cent., and it is possible that the greater content of combustible material might be serious in mortars used for rendering exposed to dampness due to the risk of "blowing" as a result of the expansion of the combustible particles. In large masses of concrete there may be no harmful effects due to the high carbon content, and it may be noted that the British Standard permits a loss on ignition of up to 20 per cent. for clinker aggregate in in-situ concrete for interior work not exposed to damp, and of 10 per cent. for clinker concrete for "general purposes". As is the case with Portland cements, the coarser the material the slower the hardening; cement containing 20 per cent. of ash with a specific surface of 2000 square centimetres per gramme had at one month about 12 per cent. less strength than a similar mixture in which the specific surface of the ash was 3400 square centimetres per gramme. Cement containing a proportion of fuel-ash does not comply with the current British Standard for Portland Cement.

There are no long-period tests on the durability of concrete in which this ash is incorporated, but its slow-hardening properties would be important in the case of structures in which speed of construction and the early release of shuttering are important. In the United States its chief use has been in dams, where slow hardening and the consequent smaller stresses due to shrinkage and the smaller evolution of heat during setting are advantageous. The density of the ash is about half that of Portland cement, so that the equivalent of two bags of ash are required with five bags of cement for a dilution of 20 per cent. At present the ash is a waste product of which more than three million tons are produced in Great Britain each year. Except in cases where large quantities of this diluted cement would be satisfactory and could be measured mechanically on the site, it is doubtful whether its use would appreciably reduce the cost of construction. For general purposes it could be incorporated by the cement maker, but waste products commonly become expensive when a use is found for them, and in addition to the cost at the power station the cement maker would have to pay for the transport of a bulky material, to introduce a new process for adding the ash to cement, and to provide separate storage silos and bags for ash-cement. Perhaps its most valuable use would be in the production of slow-hardening low-heat cement and a pozzolana cement for special work.

Analysis of Statically-indeterminate Structures by the Deformation Method.—III.*

(*Continued.*)

By M. SMOLIRA, Ph.D., A.M.I.C.E., D.I.C.

Frames with Circular Members.

General Case.—In analysing frames with circular members of constant cross sections, the elastic constants and, in some cases, also the load functions can be expressed in an explicit form, and coefficients prepared for various central angles. For uniformly-distributed load, for example, as in *Fig.* 27, the load functions calculated from equations (23) are

$$EI\theta_a = EI\theta_b = \int_0^\phi mds = \tfrac{1}{2}wR^3\left(\phi \sin^2\phi + \tfrac{1}{4}\sin 2\phi - \frac{\phi}{2}\right) = \tfrac{1}{2}wc_1R^3 \qquad (46)$$

$$EI\Delta_o = \int_A^B myds = wR^4[\tfrac{2}{3}\sin^3\phi + \phi\cos\phi(\tfrac{1}{2} - \sin^2\phi) - \tfrac{1}{4}\sin 2\phi\cos\phi] = wc_2R^4 \quad . \qquad (47)$$

in which $c_1 = \phi \sin^2\phi + \frac{1}{4}\sin 2\phi - \frac{\phi}{2}$.

$$c_2 = \tfrac{2}{3}\sin^3\phi + \phi\cos\phi(\tfrac{1}{2} - \sin^2\phi) - \tfrac{1}{4}\sin 2\phi\cos\phi \quad . \quad . \qquad (48)$$

R is the radius of the central line of a circular member, and ϕ is half the central angle. The coefficients c_1 and c_2 for various values of central angles ϕ are shown in *Fig.* 31.

In a similar way, the load functions for a concentrated load at the crown (*Fig.* 28) can be expressed as follows:

$$EI\theta_o = m_oR\frac{\phi.\sin\phi + \cos\phi - 1}{\sin\phi} \quad . \quad . \quad . \qquad (49)$$

$$EI\Delta_o = m_oR^2\frac{\phi.\sin 2\phi + \cos^2\phi + 1 - 2\sin^2\phi - 2\cos\phi}{\sin\phi} \quad . \qquad (50)$$

For a semi-circle, $\phi = \frac{\pi}{2}$; $EI\theta_o = m_oR\left(\frac{\pi}{2} - 1\right)$; $EI\Delta_o = m_oR^2$ . . (51)

in which $m_o = \frac{WR}{2}$. For more complicated systems of loading, however, equations (23) are used with integration replaced by summation.

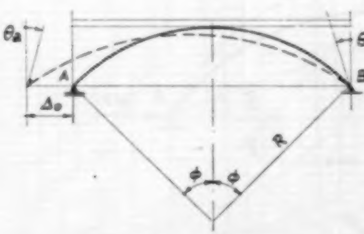


Fig. 27.

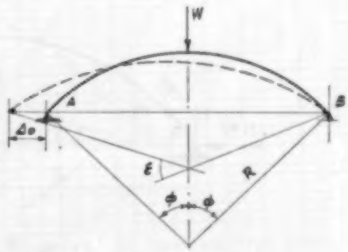


Fig. 28.

* Previous parts appeared in this Journal for July and August, 1954.

The elastic constants for a circular beam can also be expressed in explicit form, and, for unit bending moment, these are as follows (*Fig.* 29).

$$EI\varepsilon = \int_A^B m.ds = \phi.R\,;\ \ EI\alpha = \tfrac{2}{3}\phi R\,;\ \ EI\beta = \tfrac{1}{3}\phi R \quad . \quad . \quad (52)$$

$$EI\Delta^m = \int_A^B m.y.ds = R^2(\sin\phi - \phi.\cos\phi) = c_3.R^2 \quad . \quad . \quad (53)$$

Similarly, the elastic constants for a unit horizontal force (*Fig.* 30) are

$$EI\gamma = EI\delta = R^2(\sin\phi - \phi\cos\phi) = c_3.R^2 \quad . \quad . \quad (54)$$

$$EI\Delta^h = \int_A^B myds = R^3\left(\phi\cos^2\phi - \tfrac{3}{4}\sin 2\phi + \frac{\phi}{2}\right) = c_4R^3, \text{ in which } c_3 = \sin\phi - \phi\cos\phi.$$

$$c_4 = \phi\cos^2\phi - \tfrac{3}{4}\sin 2\phi + \frac{\phi}{2} \quad . \quad . \quad . \quad . \quad (55)$$

The values of coefficients c_3 and c_4, for various half central angles ϕ, are shown in *Fig.* 31. It can be seen from *Fig.* 31 that, for small central angles ϕ, the translations of joints Δ_0, Δ^m, and Δ^h are also small; the effect of curvature is therefore negligible and the beam may be treated as straight.

Example.—As a numerical example, consider a frame with a circular member and with loading as shown in *Fig.* 32. To make the analysis clear, each load is considered separately. The radius and half-central angle are

$$R = \frac{L^2}{8p} + \frac{p}{2} = \frac{60^2}{8 \times 12} + \frac{12}{2} = 43{\cdot}5 \text{ ft.,}$$

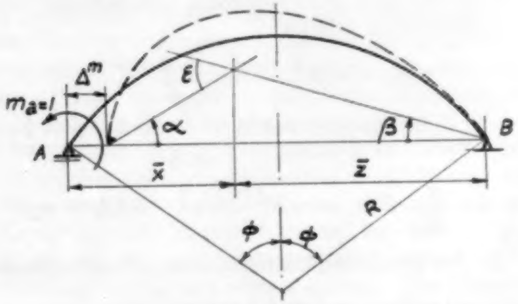


Fig. 29.

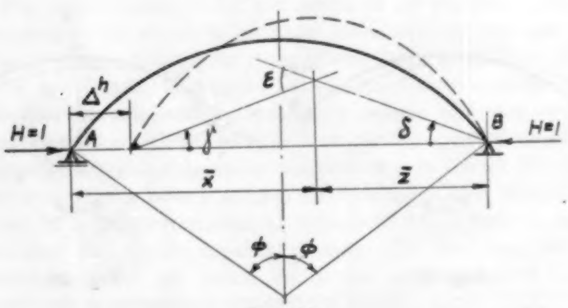


Fig. 30.

$$\sin\phi = \frac{30}{43\cdot5} = 0\cdot6900, \text{ and } \phi = 43^\circ\ 38'' \ (0\cdot7615^{\text{rad}}).$$

From *Fig.* 31 $c_1 = 0\cdot2316$, $c_2 = 0\cdot0496$, $c_3 = 0\cdot1389$, and $c_4 = 0\cdot0306$, and the elastic constants, calculated from equations (52) to (54), are

$$EI\alpha = \tfrac{2}{3} \times 0\cdot7615 \times 43\cdot5 = 22\cdot1\ ; \quad EI\beta = \tfrac{1}{3} \times 0\cdot7615 \times 43\cdot5 = 11\cdot05\ ;$$

$$EI\Delta^m = EI\gamma = 0\cdot1389 \times 43\cdot5^2 = 262\cdot5\ ; \quad EI\Delta^h = 0\cdot0306 \times 43\cdot5^3 = 2510.$$

For Uniformly-distributed Load $w = 1000$ lb. per foot:

$$EI\theta_0 = \tfrac{1}{2} \times 1000 \times 0\cdot2316 \times 43\cdot5^3 = 9{,}531{,}830\ ;$$

$$EI\Delta_0 = 1000 \times 0\cdot0496 \times 43\cdot5^4 = 177{,}598{,}250,$$

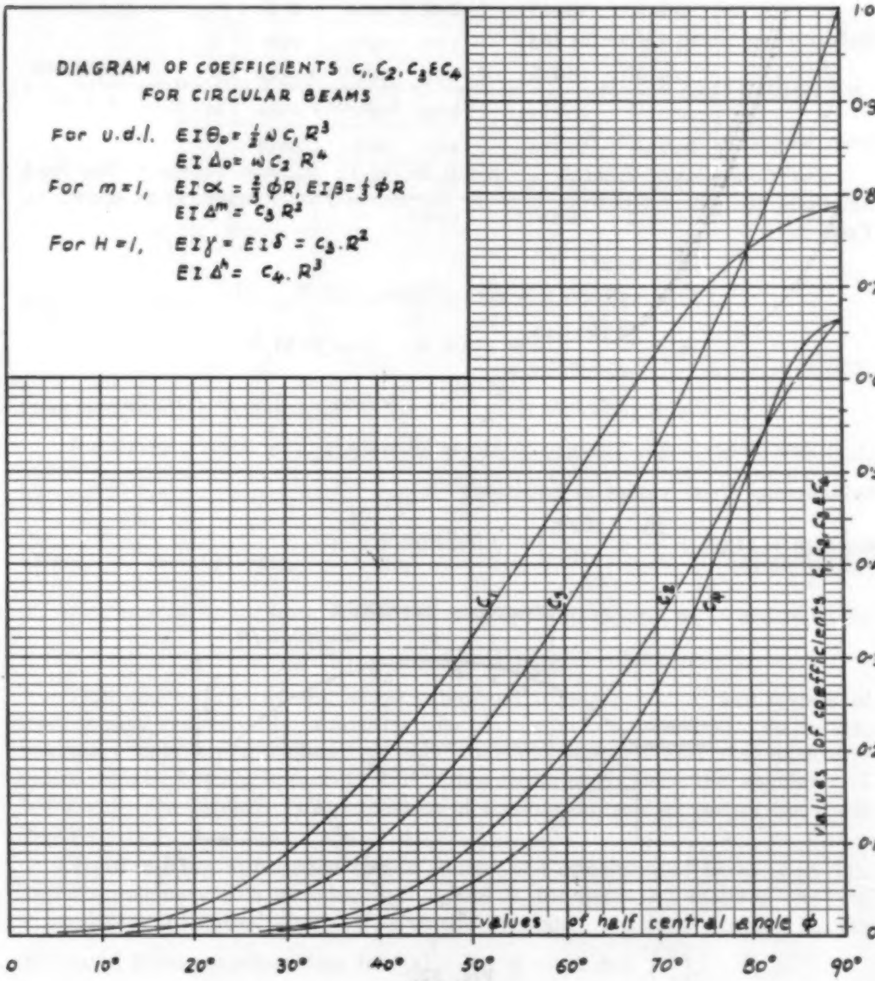


Fig. 31.

and, from (23),

$$m_a\left[22\cdot10 + 11\cdot05 + \frac{16}{3} + \frac{262\cdot5}{16} + \frac{262\cdot5}{16} + \frac{2510}{2 \times 16^2}\right] = 9{,}531{,}830 + \frac{177{,}598{,}250}{2 \times 16},$$

from which $m_a = 197{,}930$ ft.-lb.

For Concentrated Load W = 10,000 lb. at the Crown: From equations (49) to (51),

$$EI\theta_o = 43\cdot5\frac{10{,}000 \times 30}{2} \times \frac{0\cdot7615 \times 0\cdot6900 + 0\cdot7238 - 1}{0\cdot6900} = 2356\cdot5.$$

$$EI\Delta_o = \frac{10 \times 30}{2} \times \frac{43\cdot5^2}{0\cdot6900}(0\cdot7615 \times 0\cdot9989 + 0\cdot7238^2 + 1 - 2 \times 0\cdot6900^2 - 2 \times 0\cdot7238) = 47{,}411{,}000.$$

Substituting these values in (23),

$$m_a\left(22\cdot10 + 11\cdot05 + \frac{16}{3} + \frac{262\cdot5}{16} + \frac{262\cdot5}{16} + \frac{2510}{2 \times 16^2}\right) = 2{,}356{,}500 + \frac{47{,}411{,}000}{2 \times 16},$$

from which $m_a = 50{,}370$ ft.-lb.

For Concentrated Load W = 10,000 lb. *at* 12 *ft. from support*: The load functions are calculated from (23) by the method of summation as shown in *Table* 1.

$$\Delta x = 5\cdot5212 \text{ ft.}$$

$$EI\varepsilon = 558{,}000 \times 5\cdot5212 = 3{,}080{,}830.$$

$$\bar{x} = \frac{13{,}182{,}940}{558{,}000} = 23\cdot62 \text{ ft.}; \quad \bar{z} = 36\cdot38 \text{ ft.}$$

$$EI\theta_a = 3{,}080{,}830 \times \frac{36\cdot38}{60} = 1{,}868{,}090. \quad EI\theta_b = 1{,}212{,}740.$$

$$EI\Delta_o = 5{,}190{,}400 \times 5\cdot5212 = 28{,}657{,}240.$$

Substituting these values in equations (30),

$$m_a\left(22\cdot1 + 11\cdot05 + \frac{16}{3} + \frac{262\cdot5}{16}\right) = 1{,}868{,}090 + \frac{\Delta a}{h}EI.$$

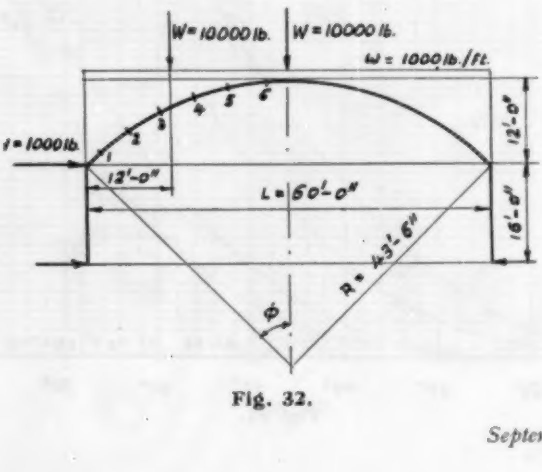


Fig. 32.

TABLE I

Point	x ft	y ft	m_o (1000 ft-lb)	$m_o . x$	$m_o . y$
1	2·05	1·85	16·5	33·82	30·52
2	6·45	5·08	51·5	332·17	261·62
3	11·30	7·80	90·5	1022·65	705·90
4	16·40	9·80	87·0	1426·80	852·00
5	21·76	11·20	76·5	1664·64	856·80
6	27·25	11·90	65·5	1784·87	779·45
7	32·75	11·90	54·5	1784·87	648·55
8	38·24	11·20	43·5	1663·44	487·20
9	43·60	9·80	32·5	1417·00	318·50
10	48·70	7·80	22·5	1095·75	175·50
11	53·55	5·08	13·0	696·15	66·04
12	57·95	1·85	4·5	260·78	8·32
Σ	—	—	558·0	13182·94	5190·40

$$m_a\left(22{\cdot}1 + 11{\cdot}05 + \frac{16}{3} + \frac{262{\cdot}5}{16} + \frac{262{\cdot}5}{16} + \frac{262{\cdot}5}{16} + \frac{2510}{16^2}\right)$$
$$= 1{,}212{,}740 + \frac{28{,}657{,}240}{16} - \frac{\Delta a}{h}EI,$$

from which $m_a = 31{,}970$ ft.-lb.

For Wind Pressure W = 1000 *lb. at top of column*: From equations (33),

$$22{\cdot}1m_a + \frac{16}{3}m_a - 11{\cdot}05m_b - \frac{262{\cdot}5}{16}m_a = \frac{\Delta a}{h}EI.$$

$$22{\cdot}1m_b + \frac{16}{3}m_b - 11{\cdot}05m_a + \frac{262{\cdot}5}{16}m_b - \frac{262{\cdot}5}{16}m_a + \frac{262{\cdot}5}{16}m_a + \frac{2510}{16^2}m_a = \frac{\Delta a}{h}EI.$$

$m_a + m_b = 1000 \times 16$, from which $m_a = 13{,}076{\cdot}4$ ft.-lb. and $m_b = 2923{\cdot}6$ ft.-lb.

Thin Elastic Rings.

Thin elastic rings of any shape submitted to the action of any system of loading may conveniently be analysed by the deformation method. As before, imaginary cuts are introduced at any convenient points and the statically-indeterminate bending moments and forces required to close the angular and linear gaps are applied. The equations of equilibrium are set out in the usual manner.

Circular Ring submitted to the Action of Concentrated Load (*Fig.* 33). —With imaginary cuts introduced at A and B, the deformed shape of the ring is as shown by dotted lines. The elastic constants and load function θ_o are calculated from equations (52) to (54). For $\phi = 90$ deg. $\left(\frac{\pi}{2}\right)$,

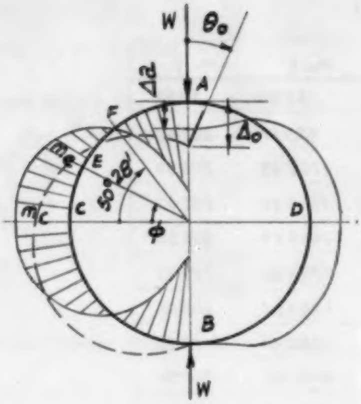


Fig. 33.

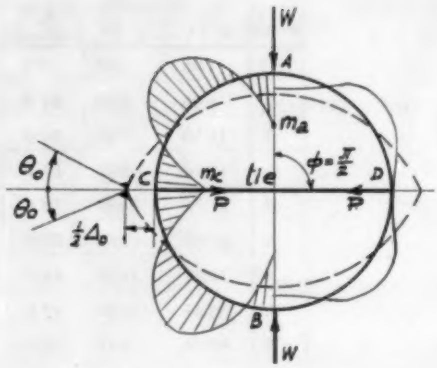


Fig. 34.

$$EI\alpha = \frac{\pi R}{3};\ EI\beta = \frac{\pi R}{6};\ EI\Delta^m = EI\gamma = R^2;\ EI\Delta^h = \frac{\pi R^3}{4};$$

$$EI\theta_o = \frac{W}{2}.\gamma = \frac{WR^2}{2};\ EI\Delta_o = \frac{W}{2}.\Delta^h = \frac{\pi WR^3}{8}.$$

The equation of equilibrium (23) reduces to $m_a(\alpha + \beta) = \theta_o$, or, substituting values of α, β, and θ, $m_a\left(\frac{\pi R}{3} + \frac{\pi R}{6}\right) = \frac{WR^2}{2}$, from which

$$m_a = \frac{WR}{\pi} \quad . \quad . \quad . \quad . \quad . \quad . \quad (56)$$

and the bending moment at C is

$$m_c = m_c^0 - m_a = \frac{WR}{2} - \frac{WR}{\pi} = \frac{WR}{2}\left(1 - \frac{2}{\pi}\right) \quad . \quad . \quad (57)$$

The bending moment at any point E on the ring is

$$m_e = \frac{WR}{2}\left(\cos\phi - \frac{2}{\pi}\right) \quad . \quad . \quad . \quad . \quad (58)$$

from which, for $m_e = 0$, $\phi = 50$ deg. 28 min. The deflection at A is calculated from $\Delta_a = \Delta_o - 2m_a\Delta^m$, from which

$$EI\Delta_a = -WR^3\left(\frac{2}{\pi} - \frac{\pi}{8}\right) \quad . \quad . \quad . \quad . \quad (59)$$

Circular Ring with a Tie submitted to the Action of Two Concentrated Loads (*Fig.* 34).—Now introduce imaginary cuts at C and D and calculate the load functions θ_o and Δ_o from (51) or (57): $EI\theta_o = \frac{WR^2}{2}\left(1 - \frac{\pi}{2}\right)$, $EI\Delta_o = \frac{WR^3}{2}$ and the equations of equilibrium for joint C are

$$\text{CAD},\ m_c\alpha + m_c\beta + \tfrac{1}{2}P\gamma = \theta_o;\ \ \text{C},\ m_c\Delta^m + \tfrac{1}{2}P\frac{\Delta^h}{2} = \frac{\Delta_o}{2} \quad . \quad (60)$$

in which P is the force in the tie.

From equations (60), $$m_e = \frac{WR}{2} \cdot \frac{\pi + 2}{\pi + 4} \qquad (61)$$

$$P = \frac{W}{1 + \frac{\pi}{4}} \qquad (62)$$

and the bending moment at A is $m_a = m_o - m_e - PR = \dfrac{3WR}{\pi + 4}$ . . (63)

Continuous Beam supported on Elastic Circular Ring (*Fig.* 35).—Statically-indeterminate bending moments are calculated from the condition of equality of deflections of the beam and the ring at B. Denoting by Δ_b the actual deflection at B, the bending moment m_b on the beam, for any shape of beam and any system of loading, can be expressed in terms of this deflection by the use of equations (1), as follows:

$$(\alpha_{ba} + \alpha_{bc})m_b = \theta_{ba} + \theta_{bc} - \left(\frac{\Delta}{L_1} + \frac{\Delta}{L_2}\right), \text{ from which } EI_b\Delta_b = f(c,P),$$

in which P is the unknown force of the beam at B and c represents beam constants, which depend on the system of loading and the geometrical shape of the beam.

Similarly, the deflection of the ring Δ_r at B can be expressed in terms of P. From equation (59), $EI_r\Delta_r = PR^3\left(\dfrac{2}{\pi} - \dfrac{\pi}{8}\right)$. Equating $\Delta_r = \Delta_b$, the force P is found. All other values can now be calculated in terms of this force.

Example.—For a two-span beam bearing on an elastic ring (*Fig.* 36), from equations (1),

$$\text{B, } \left(\frac{20}{3} + \frac{30}{3}\right)m_b = \frac{10{,}000 \times 8 \times 12}{6 \times 20}(20 + 8) - \left(\tfrac{1}{20} + \tfrac{1}{30}\right)\Delta_b EI_b$$

from which $m_b = 13{,}440 - \dfrac{\Delta_b EI_b}{200}$ and $P = \dfrac{10{,}000 \times 8}{20} + \dfrac{13{,}440}{20} - \dfrac{\Delta_b EI_b}{200 \times 20}$,

from which $$EI_b\Delta_b = 4000(4672 - P).$$

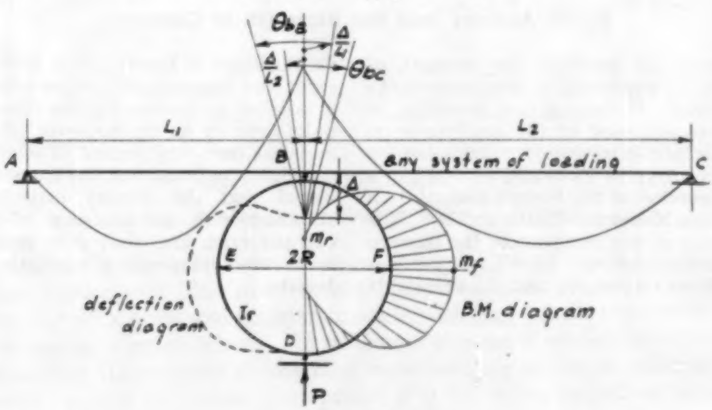


Fig. 35.

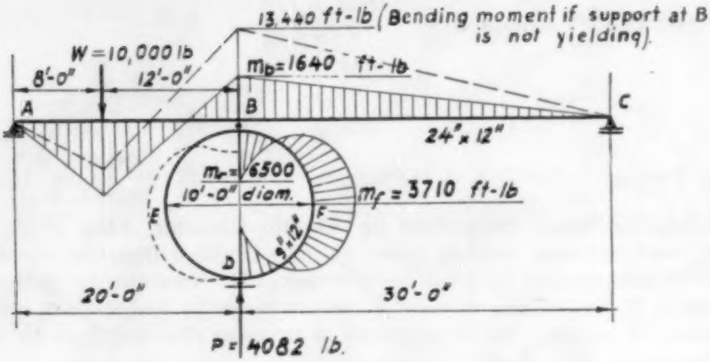


Fig. 36.

From equation (59), $EI_r\Delta_r = P \times 5^3\left(\frac{2}{\pi} - \frac{\pi}{8}\right) = 30{\cdot}4875P$. Equating $\Delta_b = \Delta_r$,

$4000(4672 - P) = 30{\cdot}4875P\frac{I_b}{I_r}$, from which $P = 4082$ lb.

The bending moments and deflections can now be calculated in terms of P as follows.

$EI\Delta_b = 4000(4672 - 4082) = 2{,}360{,}000$. $m_b = 13{,}440 - \frac{2{,}360{,}000}{200} = 1640$ ft.-lb.

$m_r = \frac{5 \times 4{\cdot}082}{\pi} = 6500$ ft.-lb.; $m_f = \frac{1}{2} \times 4{\cdot}082\left(1 - \frac{2}{\pi}\right) \times 5 = 3710$ ft.-lb.

Assuming $E = 4{,}000{,}000$ lb. per square inch,

$$\Delta_b = \Delta_r = \frac{2{,}360{,}000 \times 12}{576{,}000 \times 0{\cdot}666} = 0{\cdot}074 \text{ in.}$$

Radio Activity and the Strength of Concrete.

A METHOD of assessing the strength of concrete by measuring its resistance to the penetration of radio-active particles or rays was proposed at the conference on non-destructive testing of concrete held in January, 1954, in Paris and reported in a recent number of the French journal "La Technique Moderne—Construction." The resistance of any material to the passage of electro-magnetic rays or particles depends on its density and thickness. If its thickness is known, then with a constant and known radio-active emission it is possible by measuring the intensity of radio activity on the opposite side of the material from the source of emission to calculate the density of the barrier. It is stated that the density may be thus obtained with an accuracy of one or two per cent. and that it is possible to relate the compressive strength to the density.

Prestressed Concrete Slabs for Railway Bridges.

By P. S. A. BERRIDGE, M.B.E., M.I.C.E.

A DESIGN for railway bridges having welded mild steel main girders with a deck consisting solely of prestressed precast concrete slabs (*Fig.* 1) has been produced in the Civil Engineer's office at Paddington of the Western Region of British Railways. It is intended for single- or multiple-track bridges up to 60 ft. long,

Fig. 1.—A Bridge of 30-ft. Span.

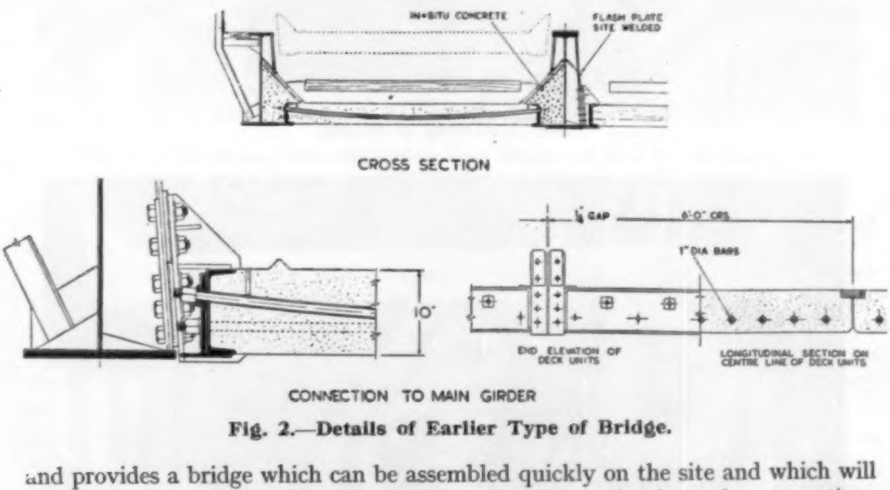


Fig. 2.—Details of Earlier Type of Bridge.

and provides a bridge which can be assembled quickly on the site and which will give long service with little maintenance. Erection is simple as the connections between the deck units and girders are made with high-tensile steel bolts ; false-work or staging is not required. No welding or riveting is needed during erection ; the surfaces of the concrete do not need waterproofing on top or painting on the underside ; and in the latest development (*Fig.* 6), where haunching against the girders has been eliminated, no concrete work is necessary on the site.

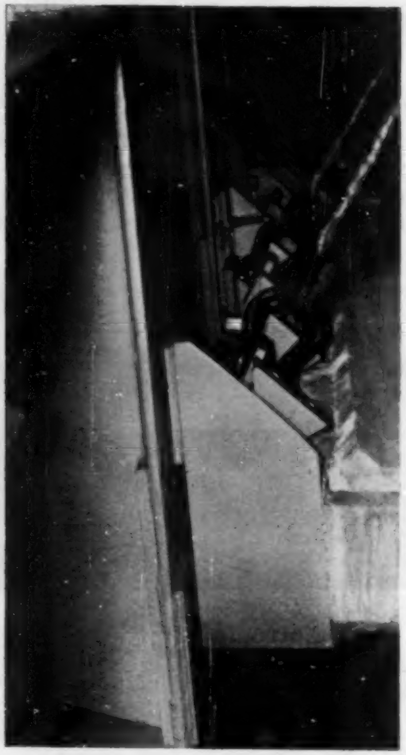


Fig. 3.—Detail of Fixing.

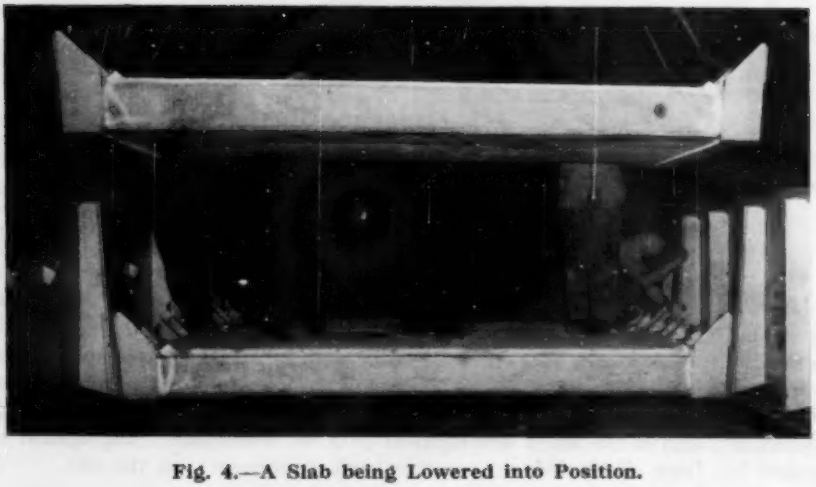


Fig. 4.—A Slab being Lowered into Position.

As is shown in *Figs.* 2 and 6, the top flanges of the girders are narrower than the bottom flanges, and the stiffeners, which are tee-shape in cross section, have a sloping surface against which similarly sloping brackets on the ends of the slabs are bolted (*Fig.* 3). The arrangement allows the main girders to be unloaded and placed in their final positions; the deck units can be lowered between them without the need for moving the girders laterally afterwards (*Fig.* 4). The design provides for the normal ballasted cross-sleeper permanent way to be continued across the bridge. The construction depth, with 6 in. of ballast under the sleepers, varies between 28 in. and 30 in. as the thickness of the slabs varies with the distance between the main girders. The distance between the girders varies from 12 ft. 5 in. for shorter spans to 15 ft. 8 in. for longer spans. The width of the deck units, measured in the direction of the track, varies from 5 ft. 9 in. to

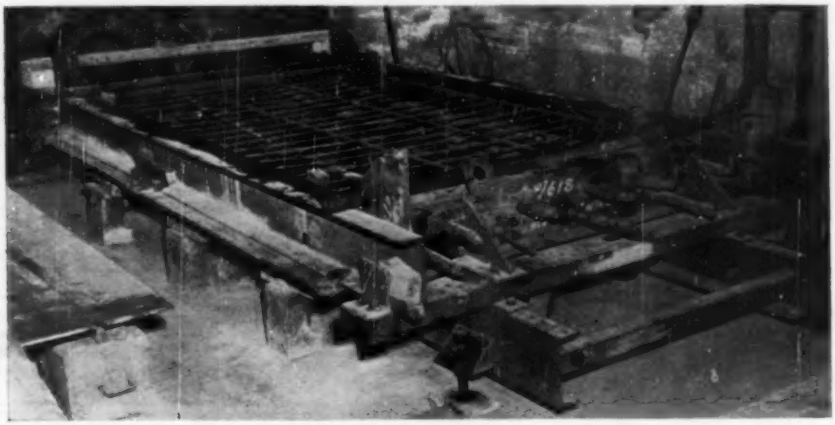


Fig. 5.—The Reinforcement, Tubes, and Steelwork in a Mould Ready for Concreting.

8 ft. 9 in., the latter being the largest which can be conveyed horizontally on a railway truck.

The deck units are designed to span between the centres of the main girders. They are not connected to one another, so that there is no interaction between the decking and the main girders. At the ends of the slabs are mild-steel channels or built-up welded beams which support the units and form the anchorages for the prestressing bars. Two welded steel brackets projecting from this steelwork are connected to the girder-stiffeners with high-tensile bolts. Plates welded to the sloping face of the brackets and resting on similar plates welded on the face of the stiffeners resist the shearing force at the connections while the bending moments are resisted by the high-tensile bolts tightened to within 85 per cent. of the yield point by torque-limiting spanners. The shear-plates serve as ledges on which the units are rested prior to being bolted, and, as the holes are $\frac{1}{16}$ in. larger than the bolts, the units are positioned temporarily with parallel drifts.

A high degree of accuracy is required in matching the sloping face of the brackets with the contact surface of the stiffeners; to achieve this a steel jig is

used to keep the steelwork at the ends of the slabs in correct alignment while the concrete is being cast. The slabs are reinforced at right-angles to the prestressing bars with $\frac{7}{16}$ in. diameter mild steel bars (*Fig.* 5). The tubes for the high-tensile prestressing bars are kept in place by wiring them to the reinforcement. Steel plates are used to form the bottom and sides of the mould. Concrete consisting of $2\frac{1}{2}$ cu. ft. of Portland cement, 4 cu. ft. of sand, and $7\frac{1}{2}$ cu. ft. of $\frac{1}{2}$-in. limestone, and a water-cement ratio of 0·4 are used. Internal vibrators are used to consolidate the concrete. The crushing strength after 28 days is between 8500

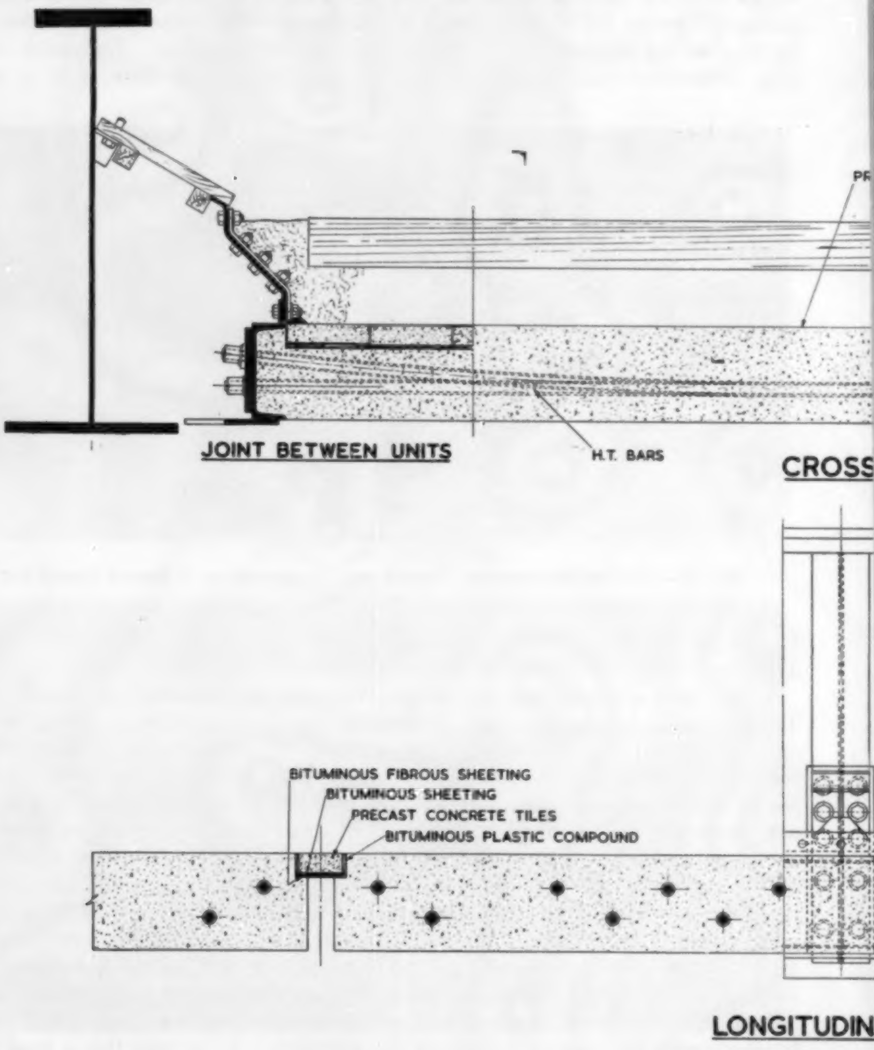
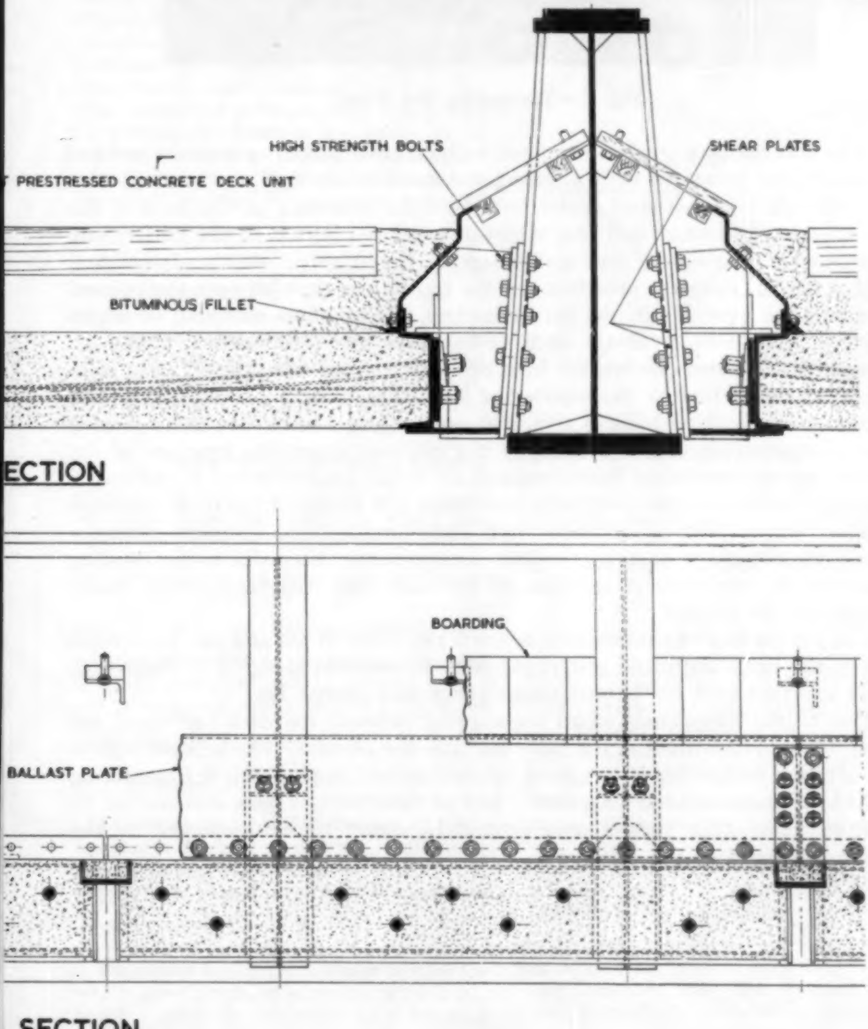


Fig. 6.—Details of t

and 9000 lb. per square inch, compared with 7500 lb. per square inch required by the specification. The maximum compressive stress allowed in the design is 2500 lb. per square inch. Seven days after casting the concrete, the prestressing bars are inserted and the nuts tightened with a spanner to avoid any risk of the steelwork being displaced when the units are removed from the jig. The slabs are prestressed twenty-eight days after casting, the bars being tensioned in pairs from one end only to a stress of 42 tons per square inch (*Fig.* 7).

On the first two bridges constructed (*Fig.* 2) the space between the ends of



later type of Bridge.

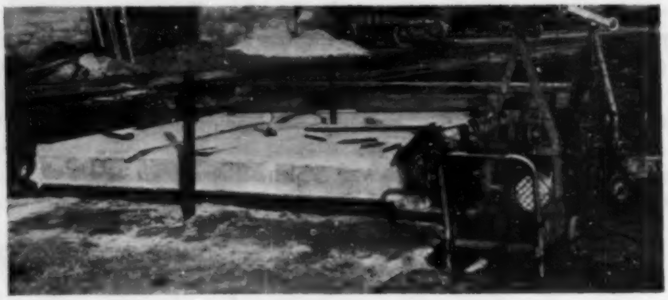


Fig. 7.—Tensioning the Bars.

the slabs and the main girders was filled with concrete placed against the webs of the girders and protected with a waterproof membrane which was overlaid with tiles. On later bridges steel plates bolted to the steelwork at the ends of the slabs contain the ballast and this steelwork, and the insides of the girders, are left accessible for painting and maintenance. Removable " weather-boarding " of either steel or timber is used to cover the tops of the gaps between the ballast-plates and the girders. In the earlier bridges, the brackets consisted of angles welded to the steelwork at the ends of the slabs and positioned so that each girder-stiffener carried one bracket from one slab and one from the adjacent slab. This arrangement limited the number of bolts that could be accommodated in the connections and, as bolts of 1 in. diameter or larger were difficult to tension to the comparatively higher loading in the confined space, the brackets of the later bridges are tee-shaped in section, and are at the quarter-points in the length of the slabs. This enables $\frac{7}{8}$-in. bolts to be used. A torque of 370 ft.-lb. required to tighten these bolts is attained with torque-multiplying spanners giving a mechanical advantage of 1 to 7. This arrangement also reduces the bending stresses in the steelwork at the ends of the slabs, but requires twice as many stiffeners on the girders.

The top surface of the concrete is given two coats of tar and the 3-in. joints between the units are made watertight with bituminous sheeting overlaid with precast concrete tiles set in bituminous compound poured hot.

Due to the importance of an accurate fit between the deck units and the girders, the units are made in the same works as the girders. The superstructures for four of the bridges have been made by the Fairfield Shipbuilding & Engineering Co., Ltd., at their works at Chepstow ; two of these bridges were also erected by this firm. The other bridges were erected by direct labour employed by the District Engineers of the Railway.

Design Diagrams for Sections subjected to Bending and Direct Forces.

When the point of application of an eccentric force is near the edge of a section, it is generally advisable to design for the maximum permissible compressive stress in the concrete and a lower tensile stress in the reinforcement. Although an increase in the tensile reinforcement will result this is counterbalanced by a reduction of the amount of compressive reinforcement, so that the total amount will be smaller. Diagrams for rectangular sections are published in the 1951 edition of "Beton Kalender" based upon the adaptation by Pucher of the work of Mörsch for given ratios of $r = \frac{t}{c}$.

With reference to the dimensions and forces shown in *Fig.* 1, the method of using the tables is as follows.

Compute the "relative" moments $M_e = M \pm Ne$ and $M_e' = M \mp Ne$. The upper signs apply if N is a thrust, and the lower signs if N is a pull. The parameters ρ and ρ' are calculated from $\rho = \frac{M_e}{cbd^2}$ and $\rho' = \frac{M_e'}{cbd^2}$ for which the percentages of reinforcement μ' and μ may be taken from the diagrams which are based upon a modular ratio m of 15 and for cover ratios of $\frac{d'}{d} = 0{\cdot}05$ for *Fig.* 3, and $\frac{d'}{d} = 0{\cdot}10$ for *Fig.* 4. The method of using these is shown in the key diagram (*Fig.* 2), and it should be observed that ρ is related to μ' and ρ' to μ. The area of reinforcement required is $A_t = \mu \times \frac{bd}{100}$ and $A_c = \mu' \times \frac{bd}{100}$.

The most suitable distribution of reinforcement for any given case is obtained by taking the values of μ and μ' from the appropriate ρ' and ρ curves for a number of values of $\frac{t}{c}$.

Example 1.—A rectangular section for which $D = 20$ in., $d = 18$ in., $d' = 2$ in., and $b = 10$ in. is subjected to a bending moment of 500,000 in.-lb. and a thrust N of 45,000 lb. Determine the reinforcement if the maximum permissible stresses are $t = 18{,}000$ lb. per square inch and $c = 1000$ lb. per square inch.

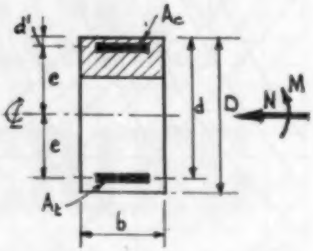


Fig. 1.

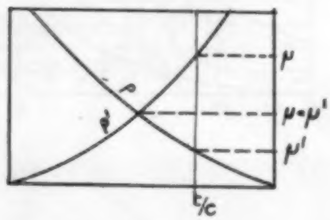


Fig. 2.

$M_e = 500{,}000 + (45{,}000 \times 8) = 860{,}000$ in.-lb.

$M_e' = 500{,}000 - (45{,}000 \times 8) = 140{,}000$ in.-lb.

$$\rho = \frac{860{,}000}{1000 \times 10 \times 18^2} = 0{\cdot}266.$$

$$\rho' = \frac{140{,}000}{1000 \times 10 \times 18^2} = 0{\cdot}043.$$

(*a*) Consider the case of equal reinforcement on each face.

As $\frac{d'}{d} = \frac{2}{18} = 0{\cdot}111$, *Fig.* 4 is used.

From the intersection of the ρ and ρ' curves, $\mu' = \mu = 0{\cdot}5$ is obtained with $\frac{t}{c} = 14$.

Hence $A_t = A_c = 0{\cdot}5 \times \frac{10 \times 18}{100} = 0{\cdot}9$ sq. in. and $t = 14 \times 1000 = 14{,}000$ lb. per square inch.

(*b*) Consider the case where tensile reinforcement $A_t = 0{\cdot}6$ sq. in. is available.

$$\mu = 0{\cdot}6 \times \frac{100}{10 \times 18} = 0{\cdot}333.$$

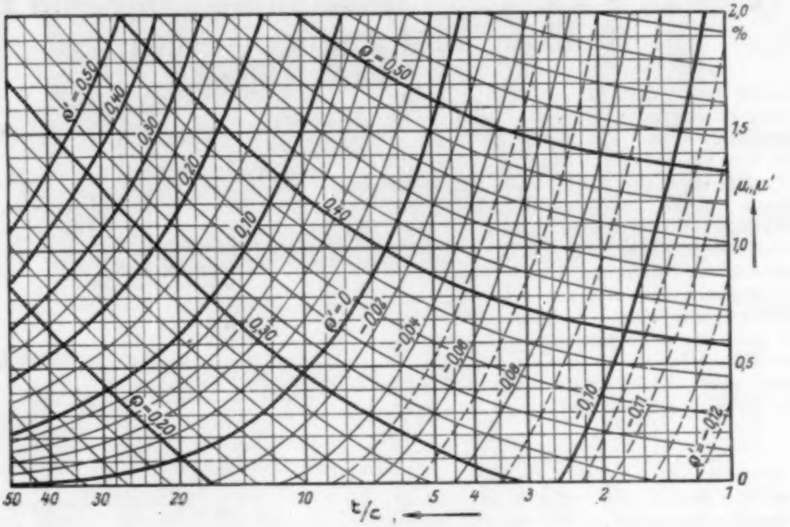


Fig. 3.—$\frac{d'}{d} = 0{\cdot}05$.

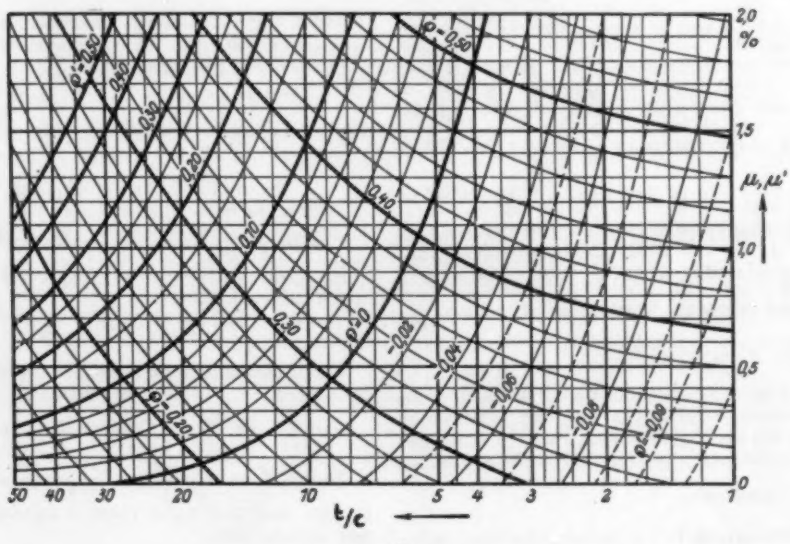


Fig. 4.—$\frac{d'}{d} = 0{\cdot}1$.

TABLE I

t	$\frac{t}{c}$	μ	μ'	A_t	A_c	$A_t + A_c$
lb. per sq. in.		%	%	sq. in.	sq. in.	sq. in.
18,000	18	0·333	0·70	0·60	1·26	1·86
16,000	16	0·400	0·60	0·72	1·08	1·80
15,000	15	0·450	0·55	0·81	0·96	1·77
14,000	14	0·500	0·50	0·90	0·90	1·80
12,000	12	0·625	0·40	1·12	0·72	1·84
10,000	10	0·800	0·25	1·44	0·45	1·89

From the intersection of the curve for this value of μ with the ρ' curve $\frac{t}{c} = 18$ is obtained, and the intersection with the ρ curve with an abscissa through the value of $\frac{t}{c}$ gives an ordinate $\mu' = 0{\cdot}7$.

Hence $A_c = 0{\cdot}7 \times \frac{10 \times 18}{100} \times 1{\cdot}26$ sq. in. and $t = 18 \times 1000 = 18{,}000$ lb. per square inch.

(*c*) Some cases for varying tensile stresses t in the reinforcement are tabulated in *Table* I. It will be observed that, while the total area of steel does not vary appreciably for different tensile stresses, there is considerable variation in the proportions of compressive reinforcement and tensile reinforcement. Note that the case of equal steel on both faces of the member occurs near the minimum value of the total area of steel.

Example 2.—Consider the same section for a bending moment $M = 500{,}000$ in.-lb. and a thrust $N = 80{,}000$ lb., and design for equal areas of steel on each face.

$$M_e = 500{,}000 + (80{,}000 \times 8) = 1{,}140{,}000 \text{ in.-lb.}$$

$$M_e' = 500{,}000 - (80{,}000 \times 8) = -140{,}000 \text{ in.-lb.}$$

$$\rho = \frac{1{,}140{,}000}{1000 \times 10 \times 18^2} = 0{\cdot}35.$$

$$\rho' = \frac{-140{,}000}{1000 \times 10 \times 18^2} = -0{\cdot}043.$$

From the intersection of the curves with these values of ρ' and ρ we obtain, from *Fig.* 4, $\mu = \mu' = 0{\cdot}55$ and $\frac{t}{c} = 4{\cdot}25$.

Hence $A_t = A_c = 0{\cdot}55 \times \frac{10 \times 18}{100} =$ $0{\cdot}99$ sq. in. and $t = 4{\cdot}25 \times 1000 = 4250$ lb. per square inch. The diagrams are reasonably accurate for the usual cover ratios $\frac{d'}{d}$ but, where in a particular case they are considered to be not near enough, the area of reinforcement may be obtained from the diagram for which the cover ratio is the nearest and adjusted in the following manner with sufficient accuracy for practical purposes (*Fig.* 5).

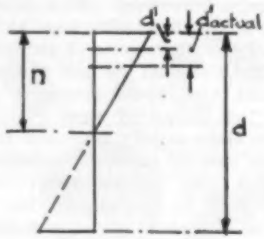


Fig. 5.

$$A_c = \mu\frac{bd}{100} \times \frac{n - 0{\cdot}05d}{n - d'_{actual}} \text{ for } Fig. \ 3.$$

$$A_c = \mu\frac{bd}{100} \times \frac{n - 0{\cdot}10d}{n - d'_{actual}} \text{ for } Fig. \ 4.$$

In these expressions the value to be assumed for n is obtained from the stress ratio given on the diagram considered. Assume in Example 2 that d'_{actual} is 3 in. From the diagram for the nearest value of $\frac{d'}{d}$, that is *Fig.* 4, the depth of the neutral axis is

$$n = \left(\frac{15}{15 + \frac{4250}{1000}}\right) \times 18 = 14 \text{ in.}$$

and the previously obtained value for A_c should be increased to

$$A_c = 0{\cdot}99 \times \frac{14 - 1{\cdot}8}{14 - 3{\cdot}0} = 1{\cdot}08 \text{ sq. in.}$$

Book Reviews.

"Theorie der Verbundkonstruktionen." By Konrad Sattler. (Berlin: Wilhelm Ernst & Sohn. 1953. Price 43 D.M.)

AFTER describing the principles of creep and shrinkage of concrete this book provides a comprehensive account of the theory of composite beams from simple reinforced concrete members to statically-indeterminate beams of prestressed concrete and structural steel. Although the mathematics appear formidable it is claimed that all the problems considered can be reduced to a few common fundamental operations. As the elastic modulus of concrete varies with time, methods are given to allow for this variation. Although for simple reinforced concrete structures allowance for flow and shrinkage need not be made, an accurate assessment of their effect appears to be desirable, and indeed necessary, for prestressed concrete and for arches. It has been shown by Dischinger that the flow of concrete has a favourable effect in reducing stresses arising from shrinkage and movements of the abutments of arches. It is considered also that the flow of concrete is important, and should always be allowed for, in the design of steel girders with concrete slabs rigidly attached to them.

In the case of statically-indeterminate structures, the theory given need be applied only to the effects due to the weight of the structure, the movements of abutments, etc., while for imposed loads the usual methods of calculation on the basis of elastic deformations will suffice. Numerical examples help to clarify many points not apparent on first reading the book.

"An Experimental Study of the Relation between the Properties of Fresh and Hardened Concrete." By Sven G. Bergström. (Stockholm: Swedish Cement and Concrete Research Institute. No price stated.)

A DESCRIPTION of an apparatus for determining the deformability of fresh concrete subjected to vibration, from which conclusions are drawn on the workability of the mixture and its liability to segregation with various periods of vibration. Tests are described in support of the contention that in some cases the strength, resistance to frost, shrinkage, and creep of concrete can be foretold by studying the results of tests made with the apparatus.

"New Ways of Servicing Buildings." (London: Architectural Press, Ltd. 1954. Price 30s.)

THE five parts of this book, each written by a different author, deal with lighting; heating of large buildings; heating of houses; sanitation, plumbing, and hygiene; and interior finishes. Some of the oldest as well as more recent methods are described, and the book is profusely illustrated.

Books Received.

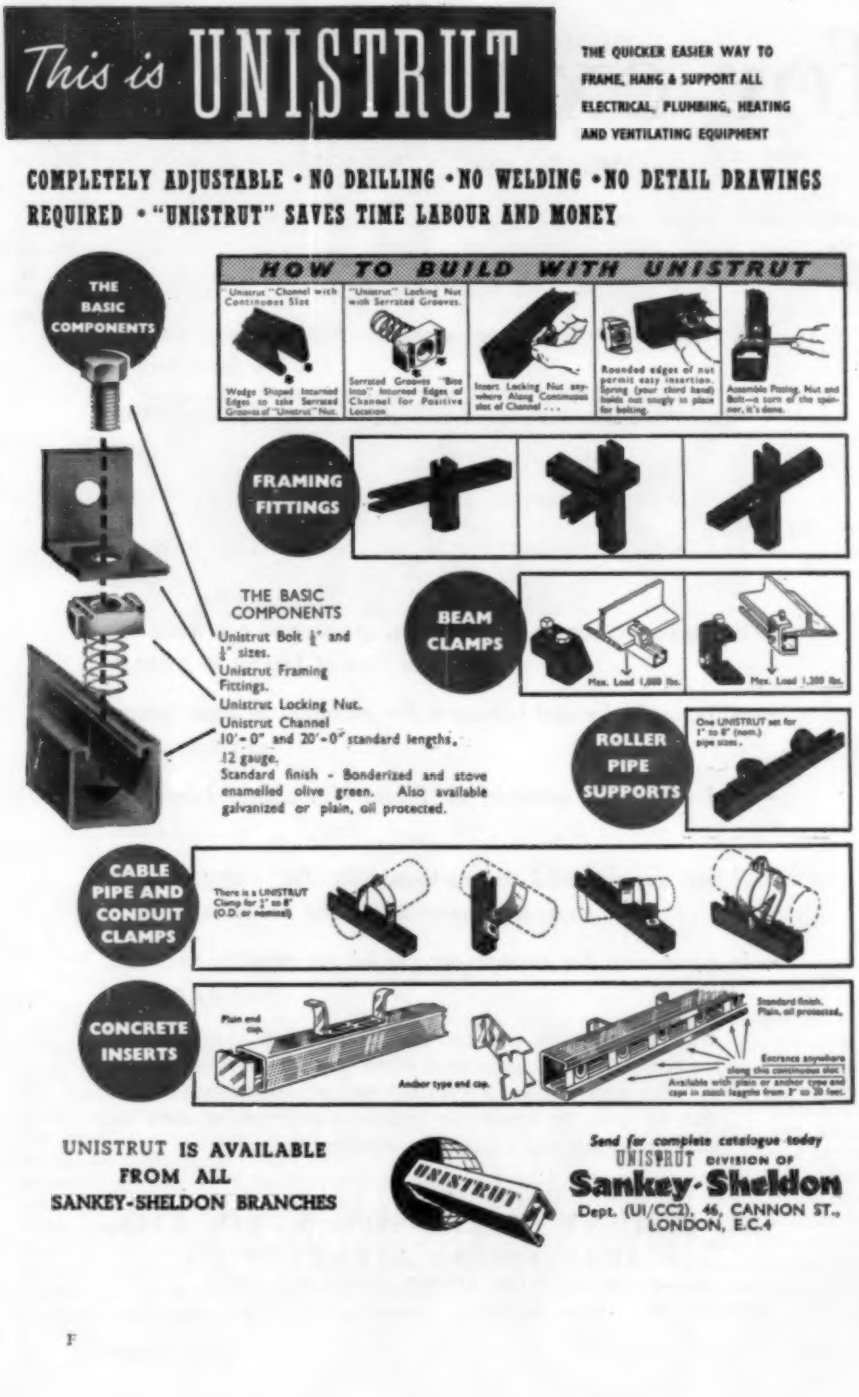
"What Every Engineer should Know about Rubber." By W. J. S. Naunton. (London: British Rubber Development Board. 1954. Price 3s. 6d.)

"The Use of Stabilised Soil for Road Construction in the U.S.A." By K. E. Clare. Road Research Technical Paper No. 29. (H.M. Stationery Office. Price. 2s. 6d.)

Pulverised-fuel Ash in Concrete.

ASH from pulverised fuel has been used as an experiment in plain concrete foundations at a housing site of the London County Council. The mixture was 1 cwt. of ordinary Portland cement to 7½ cu. ft. of 1½-in. ballast, that is a nominal 1 : 6 mixture, in which 20 per cent. of the cement was replaced by fuel ash obtained from the Littlebrook power station at Dartford. The specification required that the ash should contain not more than 10 per cent. by weight of carbon and that its fineness should comply with the requirements of B.S. No. 12: 1947 for ordinary Portland cement. The chemical analysis of the ash was as follows: SiO_2, 47·2 per cent.; Fe_2O_3, 11·6 per cent.; Al_2O_3, 30·5 per cent.; CaO, 5 per cent.; MgO, 2·1 per cent.; SO_3, 1·5 per cent.; loss on ignition, 3·6 per cent.

Because of the difficulty of handling the material on the site, the proportion of ash was related to a 1-cwt. bag of cement. The ash was therefore delivered to the site in ¼-cwt. bags. The concrete mixture comprised 1 cwt. of cement, ¼ cwt. of ash, and 10 cu. ft. of 1½-in. ballast, and a 10/7 mixer was used so that each batch contained 1 cwt. of cement and ¼ cwt. of ash. Test cubes made from different batches gave the following strengths (in lb. per square inch): At 7 days, 996, 1431, and 1369; at 14 days, 1991 and 2427; at three months, 3609 and 4916. [See Editorial Note in this number.]



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Channel at Edmonton.

THE straightening and widening of Pymmes brook, and the construction of a plain concrete invert with concrete retaining walls along its banks for a length of 620 ft. (*Figs.* 1 and 2) have recently been completed. The working space was restricted, and because one bank was inaccessible most of the work was carried out from the other bank. The brook runs through a built-up area and is subject to a very rapid rise in water level and a very high rate of flow (about 10 ft. per second) at flood periods. The highest recorded rise of water above the normal level, during the contract, was 5 ft., and the most rapid rate of rise in the same period was 1½ in. per minute. Although the weather conditions at the site might be favourable, flood water had to be expected at any time as the catchment area was subject to local storms. The water rose 2 ft. or more above the normal level on 21 occasions during the eight months the work was being constructed.

Because the width of clay walls would have seriously restricted the flow of water, and due to the uncertain nature and varying levels of the bed of the stream, steel sheet piles were used to form the cofferdams (*Figs.* 3 and 4). The piles were 12 ft. to 15 ft. long and enclosed sections of the work 80 ft. long; the length of each section was extended to 120 ft. when the amount of water that seeped into the cofferdam was known. A hammer operated by compressed air was used for driving the piles, and for extracting them a standard adaptor was fitted.

Fig. 1.

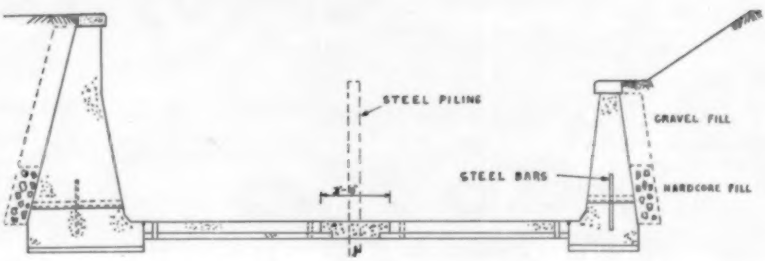


Fig. 2.

In order that the men should be employed continuously, the work proceeded upstream and downstream from the starting place, and two cofferdams were provided. The ends of the cofferdams formed on the newly-constructed invert slab were interlocking piles placed on the slab and the joints sealed with clay. The effect of scour due to the rapid flow of water during floods was considerable, and in order that the foundations should not be undermined the unconcreted strip at the centre of the invert was filled with puddled clay. The exposed ends of

completed walls were protected with corrugated steel sheets.

The walls were cast in two lifts. The distance between vertical joints was 40 ft.; 1060 ft. of the wall was 7 ft. high and the remainder 10 ft. high. Straight steel shutter plates were used; due to the varying radii of the curves it was not possible to make these up into large panels of standard size and most of the shuttering had to be reassembled to suit the curvature of different parts of the walls. All the aggregates were measured by weight, and, with the exception of the concrete filling required to bring the excavated levels up to the underside of the invert slab, all the concrete comprised 112 lb. of Portland cement, 250 lb. of sand, 300 lb. of $\frac{3}{16}$-in. to $\frac{3}{4}$-in. aggregate, and 350 lb. of $\frac{3}{4}$-in. to $1\frac{1}{2}$-in. aggregate. The water-cement ratio was 0·55.

The specification required that the minimum crushing strength of 6-in. cubes should be 3300 lb. at 28 days. As this strength was obtained at seven days, experiments were made to obtain the specified strength with less sand and cement, but leaner mixtures reduced the workability and the quality of the finish. The concrete in the invert was compacted with poker and tamping vibrators, and the walls were consolidated with poker vibrators only. The allowable compaction factor was 0·79. Difficulty was experienced in obtaining a smooth surface on the lowest 2 ft. of the battered face of the walls, probably because the walls were cast in one lift and the vibration of the last concrete placed was transmitted through the steel shutters to the lower concrete which, being partly set, was not sufficiently liquid to form a smooth surface against the shutters. This difficulty was never completely overcome, but it is thought that by using thicker steel shutters or timber shutters the surface of the lower portion of the walls would have been improved.

The central strip of the invert was completed with the use of prefabricated portable cofferdams, made of steel shutter-plates with rubber seals at their bases. This part of the work was concreted when the water level was normal, and kentledge was placed on the cofferdam to prevent it from being moved by the flow of the stream.

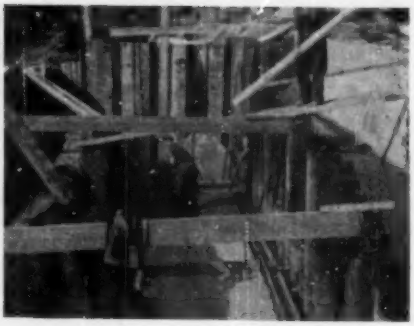


Fig. 3.

Fig. 4.

The work was carried out for the Lee Conservancy Catchment Board by Messrs. Fitzpatrick & Son (Contractors), Ltd. The foregoing notes were compiled by Mr. J. Lindsay Smith, M.A., A.M.I.C.E., D.I.C., the agent for the contractors.

A Lightweight Prestressed Bridge.

A ROAD BRIDGE recently completed in Sicily comprises seventeen spans of 75 ft. and four spans of 62 ft. The longitudinal beams are made up of prestressed precast hollow units cast in sections about 7 ft. long. One shutter 7 ft. 2 in. high was used to cast all the 950 parts of the beams. The dead load of the whole structure is 140 lb. per square foot of road surface.

There are five beams 3 ft. 7 in. deep with sides 4 in. thick at 4-ft. 9½-in. centres. The casting yard was 25 miles from the site. Only 5 per cent. of the structural concrete was placed in situ.

Holes for the prestressing cables were formed by steel bars which were pulled out of the concrete after it had set. The bars were placed in the upright shutter, the concrete placed, and vacuum mats were applied with vibration. The shutter was stripped within an hour of the application of the vacuum mat.

The bars were placed in different positions in the shutter so that the cables would have the required shape. The cables were then threaded through the holes in the beams, and the joints between the parts forming the beams were grouted with quick-setting cement. Each cable comprised eighteen 0·2-in. diameter wires, which were tensioned 24 hours after the joints had been grouted. The cables were not grouted until three months later in order to allow for deformations in the concrete resulting from shrinkage and creep. Dr. Fernando Piccinni, of Ferrocemento, Rome, designed the bridge. Our illustrations and the foregoing notes are from "Engineering News-Record" for December 17, 1953.

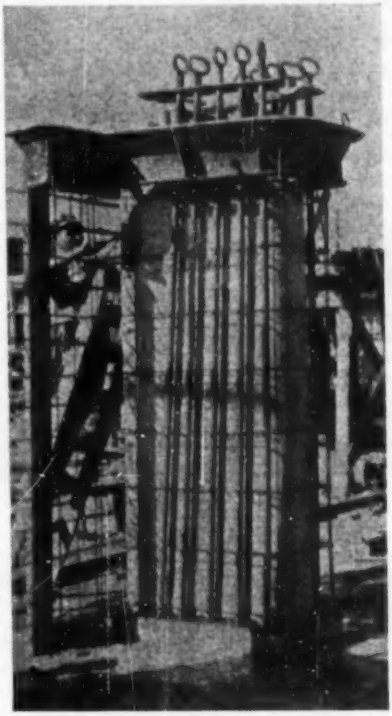


Fig. 2.—Mould for Making Parts of Beams.

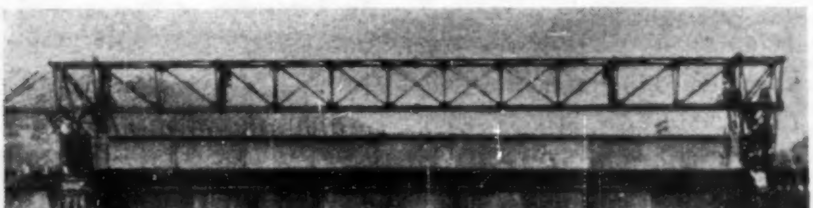


Fig. 1.—A Span of a Bridge in Sicily.

"The Load Factor against Failure."

THE following is from the report of the Building Research Board for the year 1953:

In recent years there has been an increasing tendency for structural engineers to consider a new approach to design. In this, the old method of checking that the stresses throughout a structure, for the assumed conditions of working load, are less than certain permissible values, is largely abolished. In its place a design philosophy is being developed of which the main principles are (1) that the load that will just cause failure of the structure is sufficiently greater than the working load, so that the probability of failure during the required life of the structure is less than a specified limit; (2) that, for working-load conditions through the required life, the deformations of the structure shall not be such as to impair its safety or efficiency; (3) that economic considerations in the design of structures shall include full allowance for the need for, and cost of, maintenance during the life of the structure.

With regard to the first principle, the ratio of the load that will cause failure to the working load is now commonly referred to as the "load factor against failure." The value of this factor must clearly depend on the extent to which the loading of the structure, the strength of materials used in it, and the standard of workmanship adopted both in its design and in its construction, may vary from the conditions assumed in the design calculations. Much research is being done, in this country and abroad, to provide data that will enable designers to decide on suitable load factors for various types of structure. Much of the structural engineering research is concerned with the ultimate strength characteristics of structural systems, and with the possibility of deducing simple design rules that can be embodied in codes of practice.

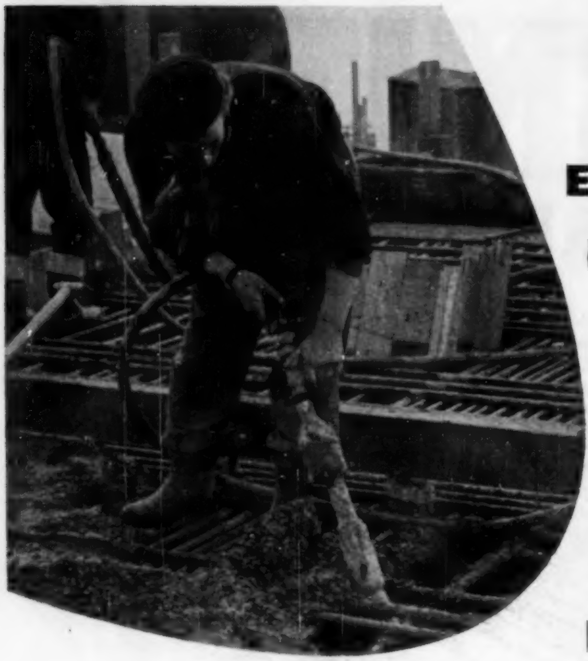
It should be noted that the load factor to be chosen in any particular case must depend not only on the load which, if applied once, would cause failure, but also on the possibility that a smaller load, if repeated many times, may cause failure by fatigue. With the tendency in modern by-laws to allow reduced margins of safety, the importance of the consideration of dynamic effects and fatigue is increased. A fatigue testing machine has recently been installed at the Station so that this aspect of structural safety can be studied.

With regard to the second principle, it is difficult to formulate explicit rules for so limiting deformations that the safety or efficiency of the structure are not thereby impaired. Deflections of reinforced concrete floor slabs, for example, may be of little importance in a warehouse, but may lead to damage to decorative ceiling finishes in a public building or to excessive maintenance of machinery in a factory. Cracking of concrete may also occur, with the resulting increased possibility of corrosion of the reinforcement. Such effects need considerable research before the load-factor basis of design can be fully exploited.

A consequential trend in the structural engineering research at the Station is towards the consideration of the strength of structures as a whole, rather than the treatment of the elements of a structure as components that can be designed separately. The structural interaction between the various elements, including parts of the structure normally regarded as infilling or cladding, has a great influence on the behaviour of the complete structure under load. Tests are being made to examine the importance of this interaction, or "composite action" as it is commonly called, both in the laboratory and in measurements on actual structures.

An Exhibition of Photographs of Concrete Buildings.

AN exhibition of photographs showing architectural developments in the use of concrete and its use in building and civil engineering at home and abroad will be held at the Royal Institute of British Architects, 66 Portland Place, London, W.1, from October 21 to 30. Most of the photographs will be of buildings built during the past twenty years, and there will also be a section dealing with the early development in the use of concrete. The exhibition is being organised by the Royal Institute of British Architects, the Cement and Concrete Association, the Prestressed Concrete Development Group, and the Reinforced Concrete Association.



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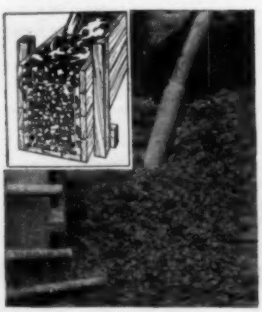
70 mm. (2¾") dia.	9,000	,, ,, ,,
100 mm. (4") dia.	10,000	,, ,, ,,

All models up to 70 mm. are available with interchangeable petrol or electric drive. The 55 mm. and 70 mm. models are also supplied for pneumatic drive.

Concrete before and after compaction by the Vibrocon spade



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Research on Prestressed Concrete.

THE following is from the Report of the Building Research Board for the year 1953 (published in July, 1954, by H.M. Stationery Office at 3*s.* 6*d.*).

Impact Strength.

The ultimate resistance of reinforced concrete beams to a single impact is superior to that of prestressed concrete beams provided that the reinforced beams are adequately reinforced with vertical stirrups. These stirrups appear to be almost as important as the main longitudinal reinforcement in influencing the impact resistance of reinforced concrete. Under repeated impacts, each insufficient in itself to cause failure, prestressed concrete beams can have appreciably greater resistance than ordinary reinforced concrete beams with normal vertical steel.

Fire Resistance.

Preliminary information based on tests made in Britain and the U.S.A. confirm that a fire resistance of two hours' duration can be achieved with little or no modification in design for simply-supported beams of 10 ft. and 16 ft. span with post-tensioned cables. Some of the results indicate, however, that further precautions may be required in the design of continuous beams. For longer periods of fire resistance, secondary mild steel reinforcement is essential and the addition of protective material may be necessary.

Static Strength.

Research on the behaviour of prestressed concrete beams under static loading indicates that simple formulæ are adequate for calculating the ultimate strength of normal types of section. In a few cases, however, there appears to be a need for more refined methods of calculation in which consideration is given to the conditions of stress and strain in the concrete and in the steel at failure.

Losses of Prestress.

Laboratory measurements of the loss of stress due to creep of hard-drawn steel wire of the type used in Great Britain show that over a period of several years it may be between 6 and 10 tons per square inch for an initial stress of about 75 tons per square inch and between 4 and 7 tons per square inch for an initial stress of about 65 tons per square inch. Records of strain in the concrete of the main prestressed concrete beams of an office building show that one-and-a-half years after the initial stressing (which amounted to 60 tons per square inch), the stress in the steel had fallen by not more than 4 tons per square inch. Further shrinkage may be expected as the concrete dries out. Evidence from this and other structures suggests that other losses of prestress may be of as great or greater importance. Such losses may be caused by friction with long cables or by slip at anchorages with short cables, or by elastic shortening of the concrete when a number of wires or cables are stressed successively and not simultaneously.

Railway Sleepers.

Static and dynamic loading tests have been made on prestressed concrete railway sleepers in which either plain wire or indented wire was used in the pre-tensioning system. Sleepers with plain wire failed, under static load applied near one end, as a result of slipping of the wire in the concrete. In similar tests there was no slipping of indented wire, and sleepers with such wire were some 15 per cent. stronger than sleepers with plain wires. Eight sleepers were subjected to dynamic loading, and it was found that there was no significant difference in strength between the sleepers with the two types of wire.

Training in Concrete Work.

We have received the following from Mr. Frank L. Donald, of Aberdeen.

"With reference to the Editorial Note in your July number on training operatives in concrete work, I am surprised that there seems to be no official recognition of such training that has been in operation for many years. I was apprenticed to a large firm of contractors in Aberdeen as far back as 1927 and received training in the making and placing of concrete in all its aspects. I and several others served an apprenticeship of three years. We attended evening classes and were taught the rudiments of building construction. We worked on sites under a competent foreman who impressed upon us the importance of the water content, the moisture contained in the sand, the need for thorough mixing, and so on. From the mixing-board we went on to the placing of concrete, steel bending and fixing, and other work. We were paid the rates current at the time. At the end of the apprenticeship we were paid full tradesman's rate, and were capable of taking charge of any kind of concrete work. I left the firm after my term, but one of the men who was apprenticed with me is still with the firm and is now their general foreman, another is in business on his own account, while I am the manager of a large precast concrete factory. We were all over 18 years of age at the commencement of our apprenticeship."

MISCELLANEOUS ADVERTISEMENTS.

Situations Wanted, 3d. a word : minimum, 7s. 6d. Situations Vacant, 4d. a word : minimum, 10s. Other miscellaneous advertisements, 4d. a word : 10s. minimum. Box number 1s. extra. The engagement of persons answering these advertisements is subject to the Notification of Vacancies Order, 1952.

Advertisements must reach this office by the 23rd of the month preceding publication.

SITUATIONS VACANT.

SITUATION VACANT. Designer-draughtsman required for London office of well-known reinforced concrete engineering contractors. Experience in reinforced concrete frames, floors, roof and staircase construction essential. Progressive post, pension scheme, alternate Saturdays. Write fully, stating salary required, to Box 323, ALLARDYCE PALMER, LTD., 109 Kingsway, London, W.C.2.

SITUATION VACANT. Reinforced concrete designer required in civil engineering department of The Coppee Co. (Great Britain), Ltd., for colliery structures (buildings, bunkers, tanks, etc.). Duties include quantities. Staff pension scheme in operation. Write, stating age, qualifications, experience, and salary required, etc., to THE COPPEE CO. (GREAT BRITAIN), LTD., 140 Piccadilly, London, W.1.

SITUATIONS VACANT. Reinforced concrete detailers required in civil engineering department of The Coppee Co. (Great Britain), Ltd. Knowledge of quantities favourably considered. Staff pension scheme in operation. Write, stating age, qualifications, experience, and salary required, etc., to THE COPPEE CO. (GREAT BRITAIN), LTD., 140, Piccadilly, London, W.1.

SITUATIONS VACANT. Clarke, Nicholls & Marcel, consulting engineers, require in their London office, for reinforced concrete work, designers and draughtsmen-detailers. Permanent positions. Good prospects. Apply in writing to 21 WESTBOURNE GROVE, LONDON, W.2.

SITUATIONS VACANT. Reinforced concrete designers and draughtsmen required by progressive firm in London, W.1, area. Varied projects. Five-days' week. Good salary, bonus and prospects. Box 4066, CONCRETE AND CONSTRUCTIONAL ENGINEERING, 14 Dartmouth Street, London, S.W.1.

SITUATION VACANT. The Cement and Concrete Association requires a civil engineer to undertake advisory work in all branches of concrete construction in Scotland. Candidates should be of Scottish nationality, between the ages of 25 and 35 years, and be graduates of a British University and/or Corporate Members of the Institutions of Civil or Structural Engineers. Some field experience and special interest in concrete work are required. Salary according to qualifications and experience. Pension scheme. The successful candidate will spend six months at the Association's research station in Buckinghamshire before taking up the appointment in Edinburgh. Applicants should write, giving full particulars, to the Scottish Manager, CEMENT AND CONCRETE ASSOCIATION, 2 Rutland Square, Edinburgh, 1.

SITUATION VACANT. Design draughtsman required for London office of Company manufacturing precast concrete products. Applicants should be experienced in prestressed designing. Opportunity to take charge of sections for those with suitable qualifications and experience. Five-days' week. House available for applicants living outside the London area. Write, stating age, education, qualifications, and experience, to Box 4069, CONCRETE AND CONSTRUCTIONAL ENGINEERING, 14 Dartmouth Street, London, S.W.1.

SITUATION VACANT. Structural and/or civil engineer (qualified) required for senior position in Scottish firm. Considerable experience of reinforced concrete design essential and some experience of precast and prestressed concrete work preferable. Write, stating qualifications, experience, and salary required. Superannuation and profit-sharing schemes in operation. Box 1980, ROBERTSON & SCOTT, 42 Charlotte Square, Edinburgh, 2.

The PORT OF LONDON AUTHORITY invite applications for a number of positions as DRAUGHTSMEN at the following scales of pay, inclusive of Pay Supplement.

The increments are annual, and commencing salaries within the scales are fixed according to qualifications and experience.

(a) *1st Class.* £627 10s. per annum by £26 5s. to £758 15s. per annum.
(b) *2nd Class.* £552 per annum by £23, by £21 to £596 per annum.
(c) *3rd Class.* £425 10s. per annum by £17 5s., by £23 to £506 per annum.

Applicants should have experience in the following:

(1) *Civil Engineering Draughtsmen*
For (a)—the design and detailing of warehouses, sheds, offices, canteens, and other buildings in reinforced concrete, steel and timber, connected with the Docks. Applicants must be able to work with the minimum of supervision.
For (b)* and (c) —detailing such structures with or without supervision.

In all cases maritime works experience and ability to make site surveys would be an advantage.

(2) *Survey Draughtsmen*
For (b)—undertaking land and building surveys and plotting the results.

(3) *Electrical Engineering Draughtsmen*
For (c)—making electrical wiring layouts for building work, under supervision.

Application forms may be obtained from the Establishment Officer, Port of London Authority, Trinity Square, London, E.C.3.

* This position is at SURREY COMMERCIAL DOCKS S.E.16.

SITUATION VACANT. Experienced draughtsman-detailer required for London office of consulting engineers. Good drawing-office experience in reinforced concrete work essential. Reply in writing, with full particulars of age, experience, and salary required to Box No. 7881, CHARLES BARKER & SONS, LTD., 31 Budge Row, London, E.C.4.

SITUATIONS VACANT. Experienced reinforced concrete designers and detailers required for permanent design staff in London office. Salary according to experience. Five-days' week. Apply W. F. G. CROZIER, PROGRESS DEPT., GEORGE WIMPEY & CO., LTD., 27 Hammersmith Grove, London, W.6.

SITUATION VACANT. Reinforced concrete draughtsman, with some knowledge of design, required for engineer's office of a firm of architects and engineers. Interesting prospects for man requiring varied experience. Write, giving full details and salary required, to RONALD WARD & PARTNERS, 33 St. George's Drive, London, S.W.1.

SITUATION VACANT. Consulting engineers, Westminster, require senior assistant experienced in road and bridge design. Good salary and prospects. Write in confidence, stating age, qualifications, and full details of experience. Box 4070, CONCRETE AND CONSTRUCTIONAL ENGINEERING, 14 Dartmouth Street, London, S.W.1.

SITUATION VACANT. Structural and/or civil engineer (qualified) required for senior position in Scottish firm. Experience of reinforced concrete and prestressed concrete essential. Commencing salary according to experience; minimum £750 per annum. Superannuation and profit-sharing schemes in operation. Box 1981, ROBERTSON & SCOTT, 42 Charlotte Square, Edinburgh, 2.

SITUATION VACANT. Diespeker & Co., Ltd., require for their London office a senior designer-draughtsman. Applicants must be experienced in reinforced concrete frames, floors, roofs, and staircase construction, and have capacity to take charge of drawing office. Permanent and progressive post. Pension scheme. Write (in confidence) to the SECRETARY, Clifton House, Euston Road, London, N.W.1, giving full particulars of qualifications, experience, and salary required.

SITUATION VACANT. Fisons, Ltd., require senior reinforced concrete designer-draughtsman capable of designing all types of reinforced concrete buildings and foundations. Pension and widow's pension funds, good salary and prospects. Apply, stating qualifications, age, and past experience to the PERSONNEL OFFICER, Fisons, Ltd., Harvest House, Felixstowe, Suffolk.

(*Continued on page* 299)

Patents Relating to Concrete.

Collapsible Cores.

A COLLAPSIBLE core for cavity walls, tunnels, well shafts, or chimney stacks comprises alternate, flexible, arcuate members (x) and straight members (MP). The members are connected by passing links (lc) through flanges (f) on the members. The links are connected to a central bar (B). To collapse the core, the bar (B) is raised, causing the flexible members to be drawn inwards, as shown in the right-hand part of *Fig.* 1. Coils of reinforcement wire (RF_2) may be placed around the core. Vertical bars (R) may connect adjacent coils. Several cores may be used side by side or end to end. The lower end of the core may have teeth, to ensure that the concrete grips the core after the core is raised. A core suitable for forming a sewer comprises members linked to a central tubular member (*Fig.* 5). The tubular member may be extended by means of threaded parts when several cores are used end to end.—British Patent No. 642,404. V. R. King. November 22, 1946.

FIG. 1.

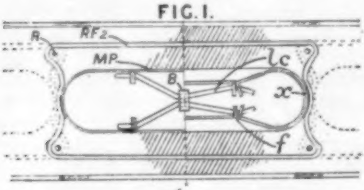
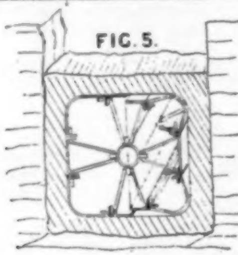


FIG. 5.



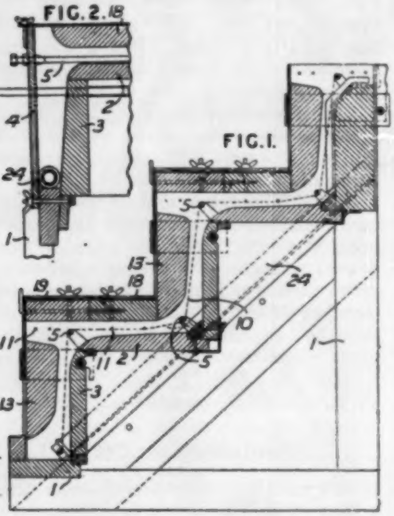
Shuttering for Stairs.

INNER casing elements, each consisting of a step (2) and riser (3), are arranged in a supporting structure (1) in stair-formation between and in relation to correspondingly

(*Continued from page* lxx)

(*Continued on p.* 300.)

stepped side-plates (4) which project above and beyond the casing elements (2, 3). Transverse reinforcement bars (5) are



then secured between the side-plates (4) opposite the angles of the stair formation, and longitudinal reinforcement wires (10) are stretched each alternately over and under the rods (5) while transverse wires (11) are stretched through holes in the side-plates (4). Reinforcement tubes or bars (24) are inserted in the lateral spaces between the plates (4) and inner casings (2, 3), and outer casing elements (13, 18) are then secured between the plates (4) in relation to the elements (2, 3) so as to leave an open space in front of each leement (18) for the concrete; after casting each step by tilting the frame (1) forward, the open space is closed by an outer casing element (19). On hardening of the concrete, the casing is dismantled, plates (4) removed, and the finished staircase taken off the frame (1).—No. 630, 329. J. P. Welschen. January 10, 1947.

[Publication of patent specifications by the Patent Office is in arrears due to the war.]

MISCELLANEOUS ADVERTISEMENTS.

(*Continued from page* 299.)

SITUATIONS VACANT. The TRUSSED CONCRETE STEEL Co., LTD., have vacancies in their London and Manchester offices for reinforced concrete designers and detailers. Five-days' week. Pension scheme. Apply, giving full particulars of age, education, and previous experience, to the Secretary, Truscon House, 35–41 Lower Marsh, London, S.E.1.

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PROFESSIONAL SERVICES. Highly qualified engineer, experienced in steel and reinforced concrete structures, including shell structures, offers services of staff of structural designers and draughtsmen. Personnel detached to employers' office or site if required. Box 4071, CONCRETE AND CONSTRUCTIONAL ENGINEERING, 14 Dartmouth Street, London, S.W.1.

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Tenders will be received until 5 p.m. on 26 October, 1954, for the construction of Moturoa Jetty in reinforced concrete, approximately 1,100 feet by 90 feet. Drawings and contract documents may be inspected in Room 14, New Zealand House, 415 Strand, London, W.C.2 (reference No. 16/778), and copies may be obtained on application direct to the consulting engineer, Mr. W. G. MORRISON, 28 Buller Street, Wellington, New Zealand.

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FOR SALE. Steel plates to sizes, pressed sections, discs, and general metalwork. Keen prices and delivery. E. STEPHENS & SON, LTD., Bath Street, London, E.C.1.

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FOR HIRE. Lattice steel erection masts (light and heavy), 30 ft. to 150 ft. high, for immediate hire. BELLMAN'S, Terminal House, London, S.W.1. Telephone: Sloane 5259.

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